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WATERFRONT HOUSING DEVELOPMENTS: THEIR EFFECT ON THE ECOLOGY OF A TEXAS ESTUARINE AREA

by

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1 INTRODUCTION

Estuaries along the United States coastline are being altered extensively by Federal, State, and private institutions. The major physical modification in these areas has been dredging and filling. More than 81,000 ha of shallow coastal bays (excluding marshes) in the Gulf of Mexico and South Atlantic areas have been altered over the past 20 years (Chapman, 1968). In Texas about 700 mi of Federal navigation channels have altered 5,265 ha of bay bottom and destroyed 2,830 ha of brackish marsh by deepening them. Spoil from these channels has filled 2,025 ha of shallow bay area and covered 9,315 ha of brackish marsh.

Presently, large areas of shallow bays and marshes are being developed for waterfront housing sites (Fig. 1). This involves dredging, bulkheading, and filling. Alteration for housing sites will probably become the greatest threat to natural marsh and bay areas unless the demand for this property decreases or the present method of altering bay areas is changed. With expanding human populations, and increased leisure time, it is likely that the demand for these areas will increase.

When areas of shallow marsh and bay are deepened or filled with spoil major changes in the bayshore environment of marine animals include: (1) reduction in acreage of natural shore zone and marsh vegetation, (2) changes in marsh drainage patterns and nutrient inputs, and (3) changes in water depth and substrates. The effects of these environmental changes on the productivity of estuarine organisms are poorly understood.

Our studies compare natural and altered areas with respect to: (1) substrates, (2) selected hydrographic variables, (3) phytoplankton productivity, (4) relative abundance of benthic macro-invertebrates, fishes, and crustaceans, and (5) the setting, growth, and mortality rates of the American oyster (Crassostrea virginica).

2 STUDY AREA AND METHODS

The study area, located in West Bay, Texas, included a natural marsh, an open bay area, and a canal area that was similar to the natural marsh before it was altered by channelization, bulkheading, and filling (Fig. 1). The developed area, which included about 45 ha of emergent marsh vegetation, intertidal mud flats, and subtidal water area prior to alteration, was reduced to about 32 ha of subtidal water area by dredging and filling. The water volume (mean low tide level) was increased from about 184,000 m³ to about 394,000 m³.

Hydrographic measurements, fish, and crustacean samples were taken the same day (between 1000 h, and 1400 h) and night (between 2200 h and 0200 h) at 2-week intervals from March 25 to October 21, 1969, at ten stations (Fig. 1). Sediment samples were taken to determine the present composition of sand, silt, and clay. Water samples for determining hydrographic variables were taken 30 cm above the bottom. Fishes and crustaceans were collected in a trawl that had a mouth opening of 0.6 m by 3 m and a stretched mesh of 28 mm in the body and 2.5 mm in the codend. At each station the trawl was towed over a distance of 200 m at 2 kn.

Primary productivity was determined twice each month at five stations (1,2,6,7, and 10) in June, July, and August by using the light- and dark-bottle technique described by Gaarder and Gran (1927). Water samples were taken 15 cm below the surface and incubated 24 h.

Benthic macro-invertebrates were sampled at 2-week intervals from March 25 to October 21 at six stations. Two stations (1 and 4) were in the canals, three (6, 7, 8) were in the natural marsh, and one (10) was in the open bay (Fig. 1). Cores of the substrate were taken with a metal cylinder 14 cm long and 9.6 cm in diameter. The number and volume of organisms, the percent of total carbon, and the volume of detrital vegetation in the substrate were determined in each sample.

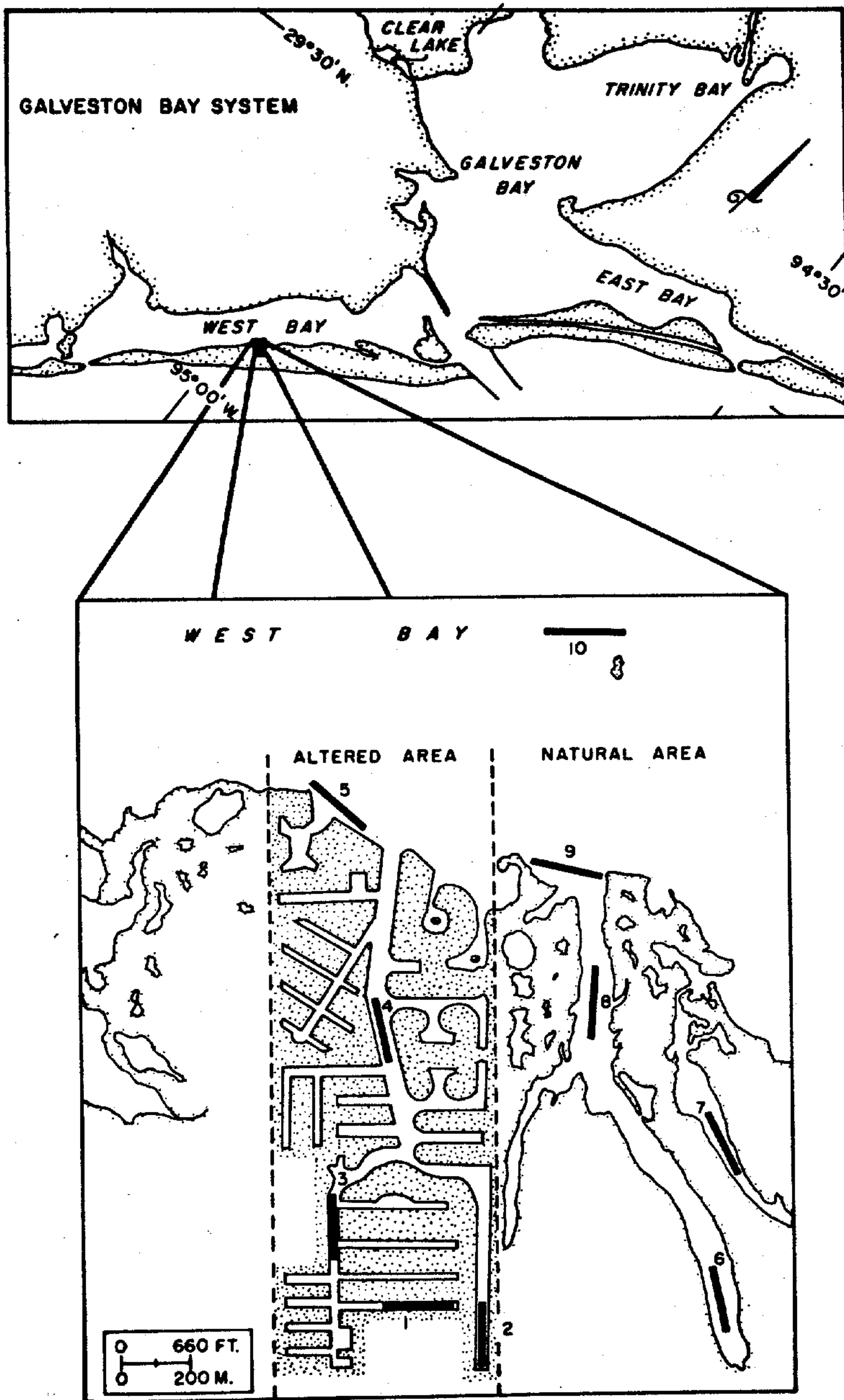


Fig. 1 The Galveston Bay system showing the study area and station locations in West Bay, Texas

Spatfall, growth, and mortality rates of the American oyster were monitored at stations 1 and 6 from February 1969 to February 1970. Asbestos plates were used to collect spatfall. Eight size groups of juvenile oysters were placed in trays at each station, and total lengths of the oysters were determined every 4 weeks. All dead oysters were replaced every 2 weeks with live oysters of similar size.

3 SUBSTRATE AND HYDROLOGY

Substrates in the canals, marsh, and bay were distinctly different (Fig. 2). Sediments were composed of higher percents of silt and clay in the canals (41%) than in the marsh (31%). The lowest percents of silt and clay occurred in the undredged bay area (17%). In a similar study in Boca Ciega Bay, Florida, Taylor and Saloman (1968) reported that sediments in undredged areas averaged 94% sand and shell and those in dredged canals averaged 92% silt and clay. Values of total carbon in the sediments were highest in the canals and lowest in the bay, but the differences were not great. The amount of detrital vegetation on and in the substrates was more than twice as great in the marsh as in the canals. Detritus was almost absent in the bay.

Eight hydrographic variables were compared. Average temperature, salinity, total alkalinity, and pH differed only slightly between areas (Fig. 3).

The average and range of dissolved organic nitrogen were highest in the marsh. A major part of the nitrogen in the marsh may have originated from cattle that graze adjacent to this area. Total phosphorus was highest, and fluctuated over the greatest range, in the canals. Runoff from fertilized lawns and seepage from septic tanks adjacent to the canals are possible sources of phosphorus.

Average values of nitrogen and phosphorus were much lower in West Bay than had been previously found in Clear Lake (Fig 1.) and in upper Galveston Bay (Pullen, 1969; Pullen and Trent, 1969), probably because domestic and industrial wastes are not discharged into the middle area of West Bay. Clear Lake is a heavily populated area, with inadequate sewage treatment facilities, and upper Galveston Bay receives domestic and industrial waste from the City of Houston via the Houston Ship Channel.

Average turbidity of bottom waters (Jackson turbidity unit - JTU) was highest in the bay, but the highest values were measured in the canals. In surface water samples, however, turbidities were over twice as high in the marsh and bay as in the canals. Our surface sample observations agree with those reported by Taylor and Saloman (1968), who stated that waters outside the developments in Florida were more turbid than those in protected canals.

Average values of dissolved oxygen were highest in the bay, intermediate in the marsh, and lowest in the canals. During the summer, oxygen dropped to critically low levels (less than 0.2 ml/l) for survival of fishes and crustaceans at the three stations (1, 2, and 3) in the canal area farthest from the bay. The annual average at stations 1, 2, and 3 combined was 3.17 compared with 4.39 ml/l. for stations 4 and 5 nearer the bay. Taylor and Saloman (1968) stated that oxygen levels were reduced during the summer over the soft sediments of housing development canals.

4 PHYTOPLANKTON

Phytoplankton productivity in the West Bay area was high compared with other marine environments at 15 cm below the water surface. Gross photosynthesis was 1.96 mgC/l day and respiration was 0.51 mg C/l day; the values ranged from 0.87 to 3.43 for photosynthesis and 0.23 to 1.19 for respiration. The average values were much higher than the May through September averages of gross photosynthesis and respiration reported by Williams (1966) for shallow estuaries along the Atlantic coast. At the 50% insolation depth, his mean values were 0.50 mg C/l day for gross photosynthesis and 0.19 for respiration. The differences were even greater than indicated because, according to Williams, the rate of photosynthesis at the depth (about 50 cm in our area) of 50% insolation is higher than at a depth of 15 cm.

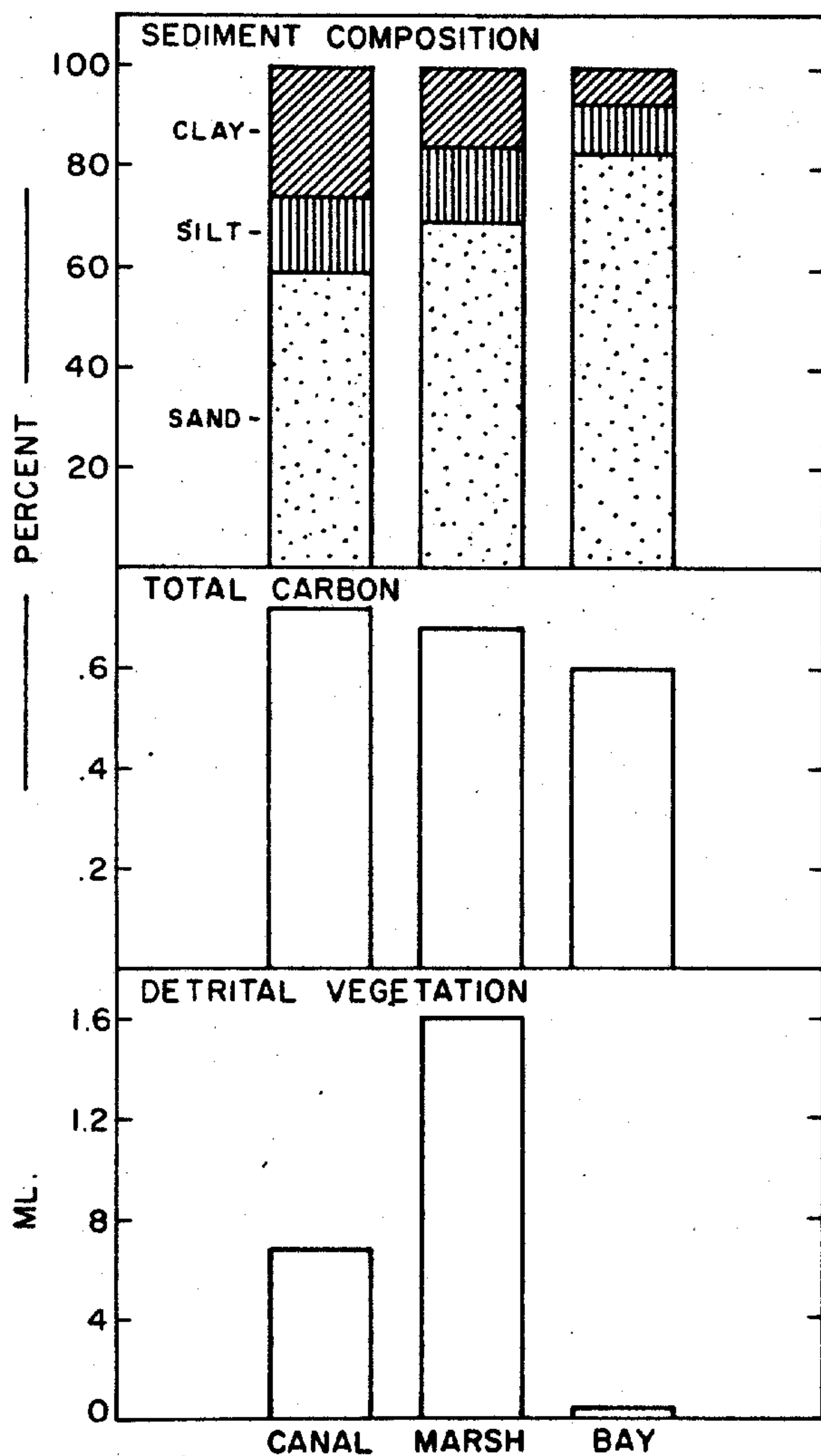


Fig. 2 Comparisons of sediment composition, total carbon, and detrital vegetation between the canals, marsh and bay

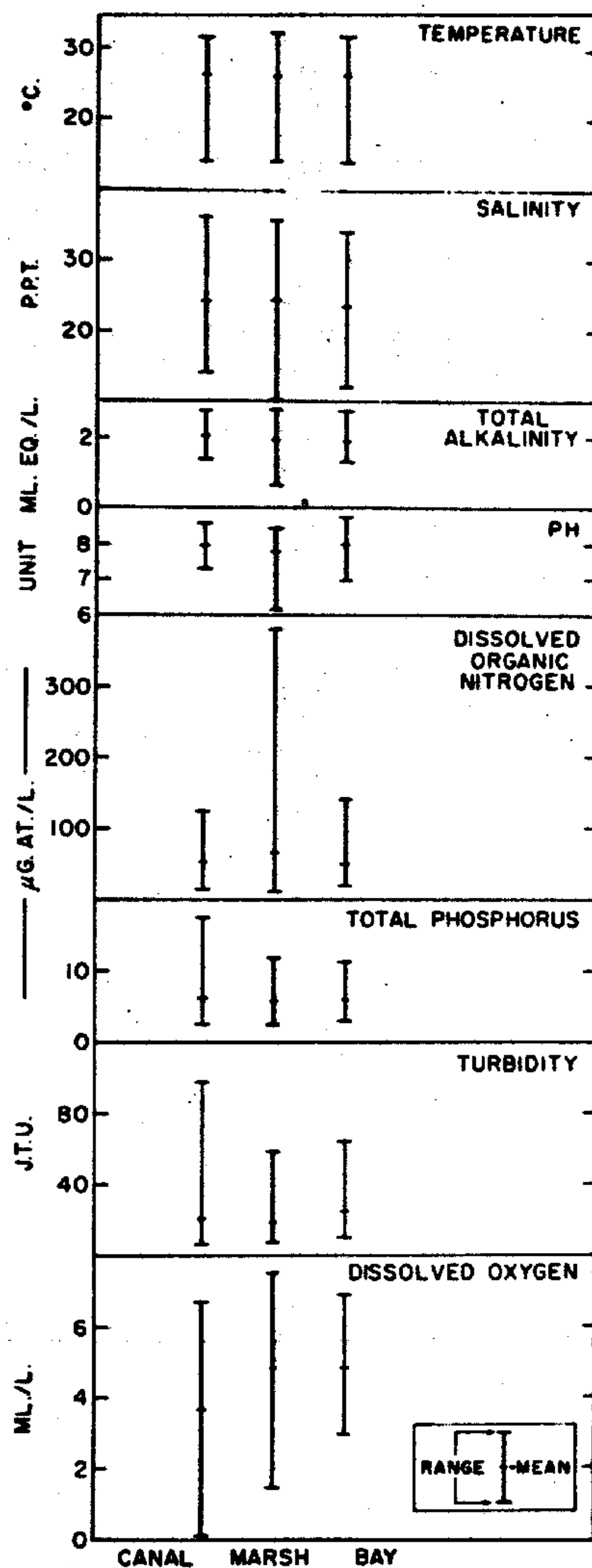


Fig. 3 Average and range values of hydrographic variables observed in the canals, marsh and bay

Net photosynthesis in the Atlantic coast estuaries was greater than most of the values from other marine environments (Williams, 1966).

Averages gross photosynthesis for June, July, and August ranged from 1.17 mg C/l day in the bay to 2.25 in the canals (Fig. 4). Average values at the canal stations were almost identical as were those at the two marsh stations. Average photosynthesis in the canals was slightly higher (8%) than in the marsh, and much higher (49%) than in the bay. In similar studies in Baco Ciega Bay, Florida, Taylor and Saloman (1968) reported that primary production of phytoplankton did not differ consistently between development canals and open bay areas.

5 BENTHIC MACRO-INVERTEBRATES

In benthic survey, polychaetes comprised 66% of the number and 44% of the volume of animals caught. Crustaceans were second in number (29%) but lowest in volume (4%). Molluscs were third in abundance (3%), but second in volume (41%). The volume of molluscan biomass was much lower than this indicates, however, because the volume includes shells. Nemerteans were lowest in number (1%) and third in volume (11%).

Benthic animals were slightly more abundant numerically and about twice as abundant volumetrically in the marsh as in the canals; they were least abundant in the bay (Fig. 5). The order of abundance varied, however, when individual groups were considered. Polychaetes of the Family Capitellidae were the dominant organisms caught (91% of all polychaetes collected), and were most abundant in the marsh and canals where substrates were composed of high percents of silt, clay, and detritus. Individuals of this family burrow through the substrate and obtain their food by ingesting organic matter that is mixed with sand and mud (Barnes, 1963). Crustaceans, most of which belonged to the Families Ampeliscidae and Corophiidae (99% of all crustaceans collected and identified), were over three times as abundant in the marsh as in the other two areas. Molluscs, mostly the genera Tellina, Tagelus, and Mulinia (95% of all molluscs collected), were numerically most abundant in the bay but they were so small in the bay that, volumetrically, the marsh had the highest standing crop. Nemerteans were most abundant in the marsh and least abundant in the bay.

6 OYSTER SPATFALL, GROWTH AND MORTALITY

About 14 times more oyster spat attached to sampling plates in the marsh than in the canal during the 12-month period. On a 600 cm² surface area, 184 attached in the marsh and 13 in the canals. These rates were much lower than those observed by Hopkins (1931) in West Bay.

Juvenile oysters, 44 mm in average total initial length, grew 72% faster in the marsh than in the canals. The yearly average increase in shell length was 52 mm in the marsh and 33 mm in the canals. Growth in the marsh was similar to the average for Texas given by Hofstetter (1965) who estimated that it takes from 18 to 24 months for oysters to reach a length of 76 mm.

The annual rate of mortality averaged 91% in the canals and 52% in the marsh. In a nearby area (Louisiana) of similar climate, Mackin (1961) noted that several tray studies showed that the normal annual loss of oyster, 1 year and older, was between 50-70% and might run as high as 90% or as low as 30%. Compared with these estimates, the mortality of oysters in the marsh was a "low average mortality" whereas oyster mortality in the canals was slightly above the "high extreme mortality" observed in the Louisiana studies.

7 FISHES AND CRUSTACEANS

Sixty-four species and 240,575 specimens of finfish and crustaceans were taken with the trawl. Of the 64 species, 54 occurred in the marsh, 52 in the canals, and 44 in the bay.

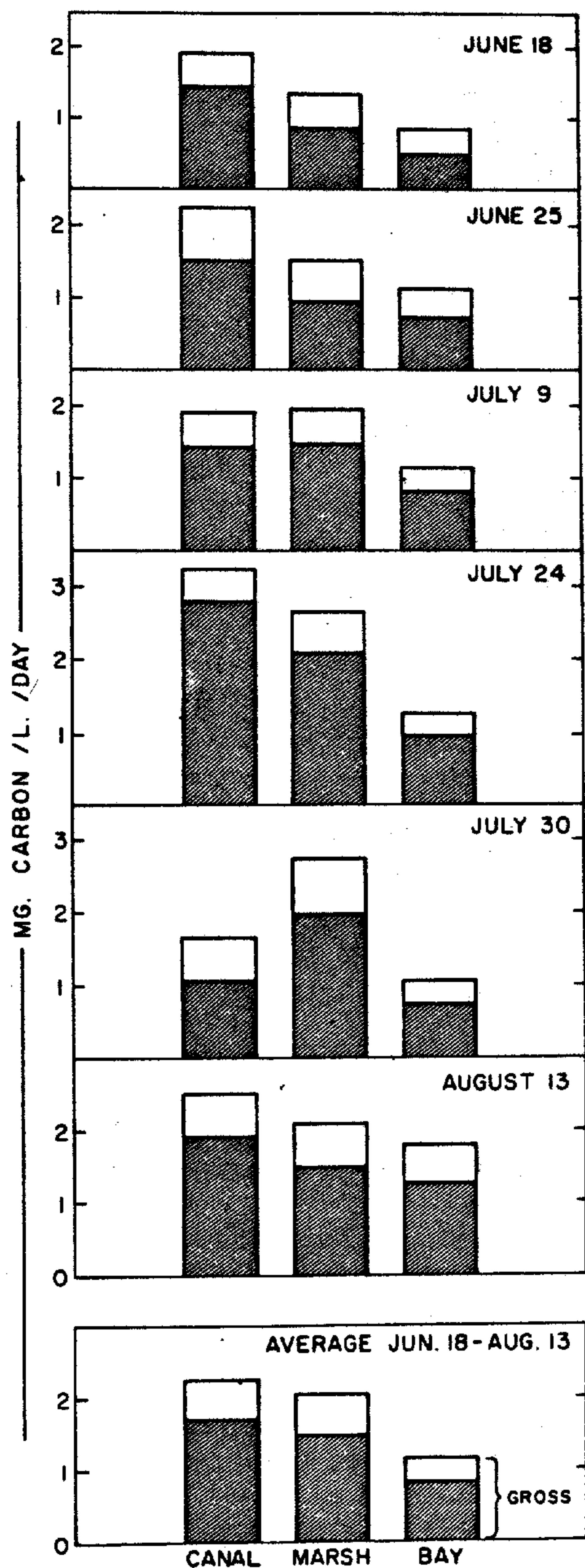


Fig. 4 Gross and net photosynthesis, and respiration by area and date, and average values for all sampling dates

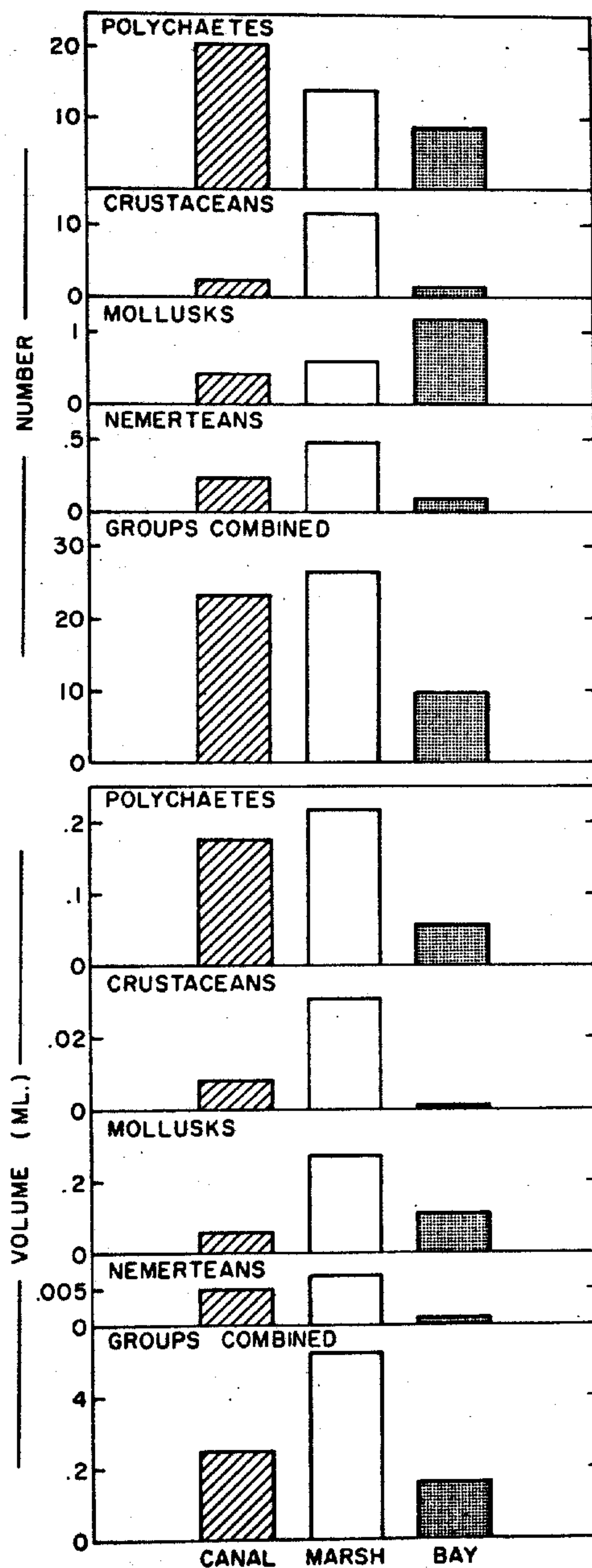


Fig. 5 Average number and volume of benthic macro-invertebrates collected per 800 cm² of bottom material by area, taxonomic group, and for groups combined

In terms of numbers of animals caught when all species were combined, the marsh was the most productive area, and the canals the second most productive. The average number of animals caught per tow was 951 in the marsh, 659 in the canals, and 412 in the bay.

The ten species caught in greatest abundance represented 96% of the total number of specimens (Fig. 6). Of the six most abundant species (89% of the total catch), brown shrimp (*Penaeus aztecus*), white shrimp (*P. setiferus*), spot (*Leiostomus xanthurus*), largescale menhaden (*Brevoortia patronus*), and Atlantic croaker (*Micropogon undulatus*) are commercially valuable and the bay anchovy (*Anchla mitchilli*) is important as food for commercial and sport fish species. The first three species were most abundant in the marsh and the last three were most abundant in the canals.

Brown shrimp, the most valuable commercial fishery species in the United States, were least abundant in the bay. These shrimp were more abundant in the canals and marsh probably because of bottom type and food availability. Bottom sediments were composed of more silt and clay, vegetative material, and total carbons in the marsh and canals than in the bay (Fig. 2). Juvenile brown shrimp prefer soft, muddy substrates with large amounts of detrital material (Williams, 1958). Benthic organisms were more abundant, and phytoplankton productivity was higher, in the marsh and canals than in the open bay. Juvenile brown shrimp feed predominantly on benthic organisms and detrital material. Williams (1955) reported that stomachs of brown shrimp from estuarine areas along the Atlantic coast contained, in order of decreasing frequency of occurrence, (1) masses of unrecognizable debris, (2) chitin fragments of crustaceans, (3) setae and jaws of annelids, (4) plant fragments, and (5) sand.

Large scale menhaden and bay anchovy were most abundant in the canals and least abundant in the bay. Both species are plankton feeders during their juvenile stages. Menhaden feed predominantly on phytoplankton, and anchovy feed mostly on zooplankton (Darnell, 1958). The abundance of these fishes in the three areas was related, although not proportionately, to phytoplankton productivity in the areas (Fig. 4).

Juvenile spot were about four times more abundant in the marsh than in the canals and open bay. This is probably related to the high abundance of crustaceans (Fig. 5) in the marsh area. In general, juvenile spot feed predominantly on planktonic and benthic micro-crustaceans (Gunter, 1945; Darnell, 1958).

White shrimp were much more abundant in the marsh than in the canals and bay. White shrimp show a more distinct preference than do brown shrimp for shallow water habitats characterized by muddy or peaty bottoms high in organic detritus and an abundance of marsh grasses (Weymouth, Lindner, and Anderson, 1933; Williams, 1955; Loesch, 1965; Mock, 1967). These factors, along with those discussed previously for brown shrimp, are important in explaining the observed distribution of white shrimp.

Atlantic croakers were most abundant in the canals and least abundant in the marsh. Why they were more abundant in the bay than in the marsh is difficult to explain. Juvenile croakers prefer soft substrates where they can obtain much of their food by digging for subsurface invertebrates and organic debris (Roelofs, 1954; Reid, 1955). This type of substrate was not present in the bay.

8 SEASONAL RELATIONS

Seasonal relations between levels of dissolved oxygen, spatfall, growth, and mortality rates of oysters, abundance of benthic organisms and fishes and crustaceans at stations 1 in the canal and 6 in the marsh are shown in Fig. 7. Oxygen levels were even more critical at station 1 than the figure indicates because: (1) the data were taken at a time of day of day that was not the most critical (about 0600 h), and (2) in our regular schedule we did not sample during times of heavy plankton blooms. Other observations revealed, however, that plankton blooms sufficient to reduce oxygen levels to zero at night and cause fish kills occurred at least four times at station 1 during June-August.

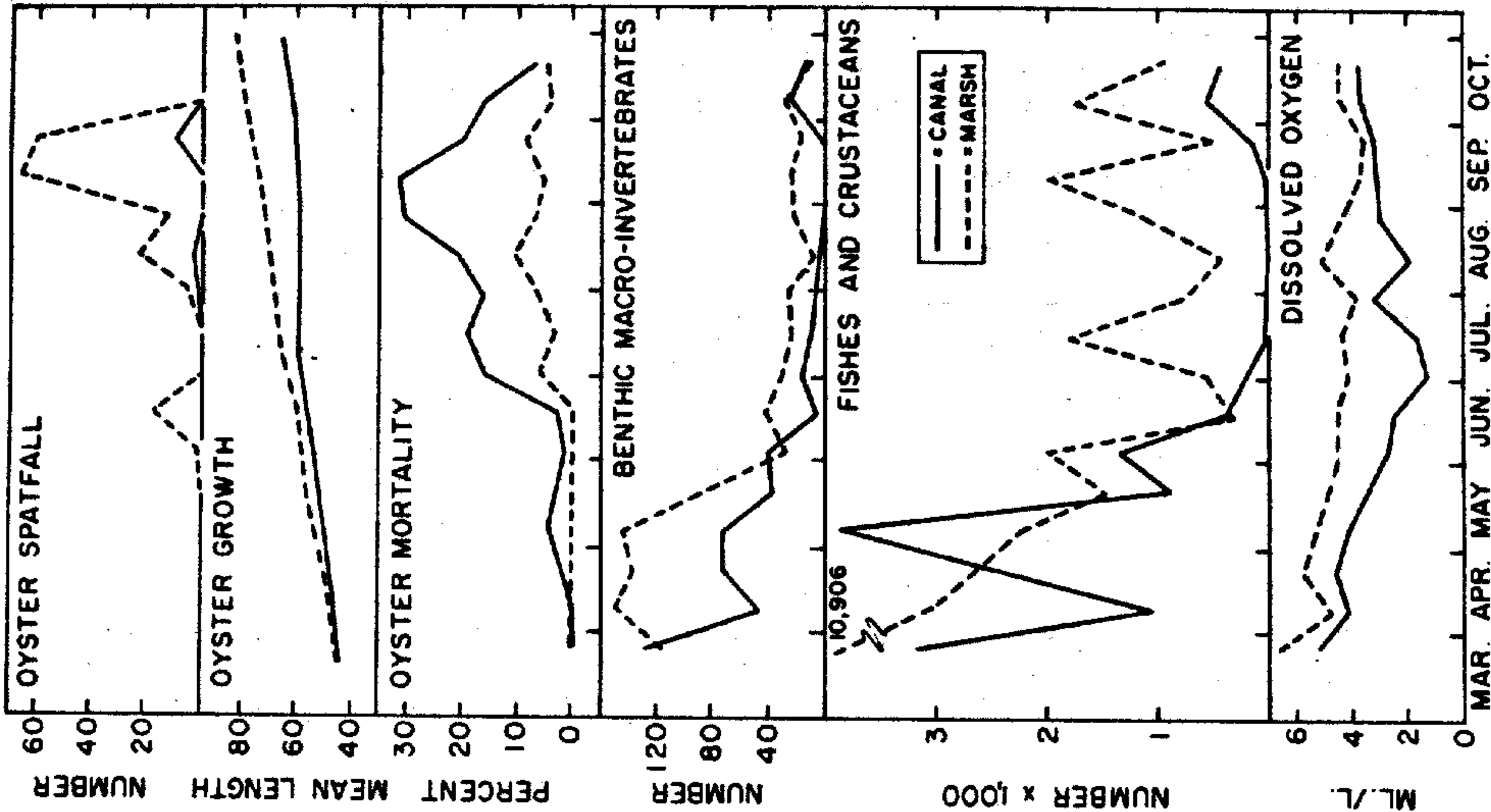


Fig. 7 Oyster spatfall, growth and 2-week mortality rates, abundance of benthic organisms, total number of fish and crustaceans caught and dissolved oxygen by date at stations 1 in the canal and 6 in the marsh

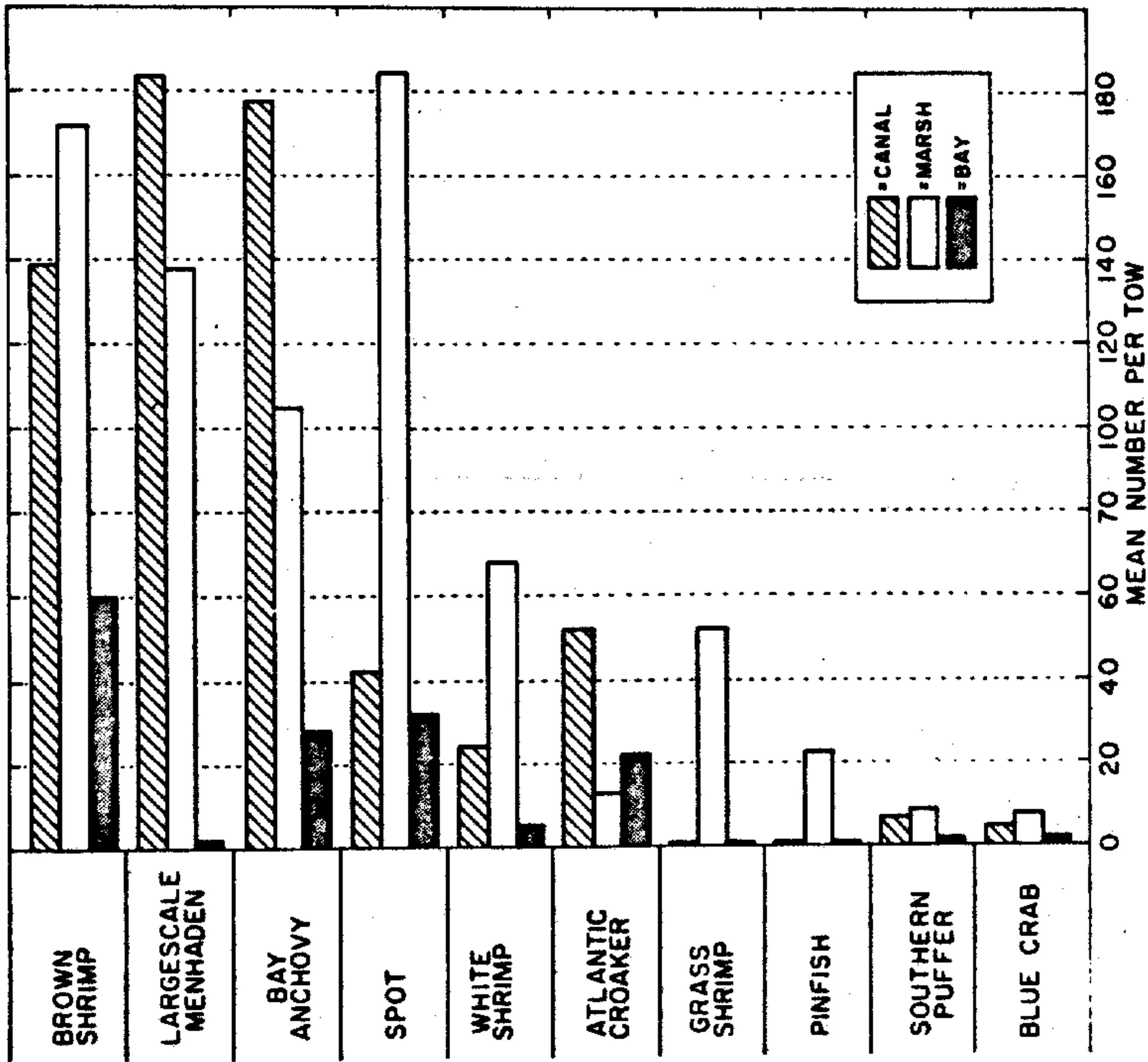


Fig. 6 The 10 species caught in greatest abundance in the trawl, with comparisons of their abundance between canals, marsh and bay

Probably poor oyster growth, high oyster mortality, and low to nil standing crops of benthic organisms, fishes, and crustaceans during June-September were directly or indirectly caused by low oxygen levels at station 1. Furthermore, stations 2 and 3 in the area of the development furthest from the bay had low oxygen levels during the summer and a smaller than average standing crop of fishes and crustaceans. Tentatively, we think poor water circulation in parts of the development canals caused conditions favorable for high populations of phytoplankters.

9 CONCLUSIONS

In general, biological productivity was highest in the marsh, intermediate in the canals of the altered area, and lowest in the open bay. Productivity in the canals, however, would probably have been much higher if dissolved oxygen levels had been higher in all canals of the altered area during the summer.

The standing crops of benthic organisms, fishes, and crustaceans in the altered area were high and we are planning studies to determine the relative contributions of vegetative material by various types of primary producers. We know that phytoplankton, attached algae, and mud diatoms are produced in the altered area. In addition, submerged sea grasses and emergent vegetation (*Spartina alterniflora* is the dominant species) are produced in the natural marsh. We do not know, however, whether the altered area is self-supporting in terms of vegetative productivity or derives much of the vegetative detritus from the natural marsh through tidal action. If the altered area is not self-supporting, and if areas of marsh are developed in ways similar to the present, then biological productivity of the estuarine zone will be reduced in relation to the acres of marsh altered.

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